Designing for Permeable Pavement: Long-Term Performance and Cost Efficiency

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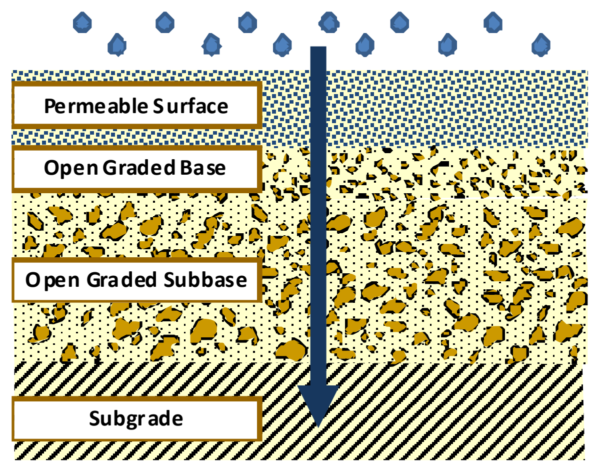
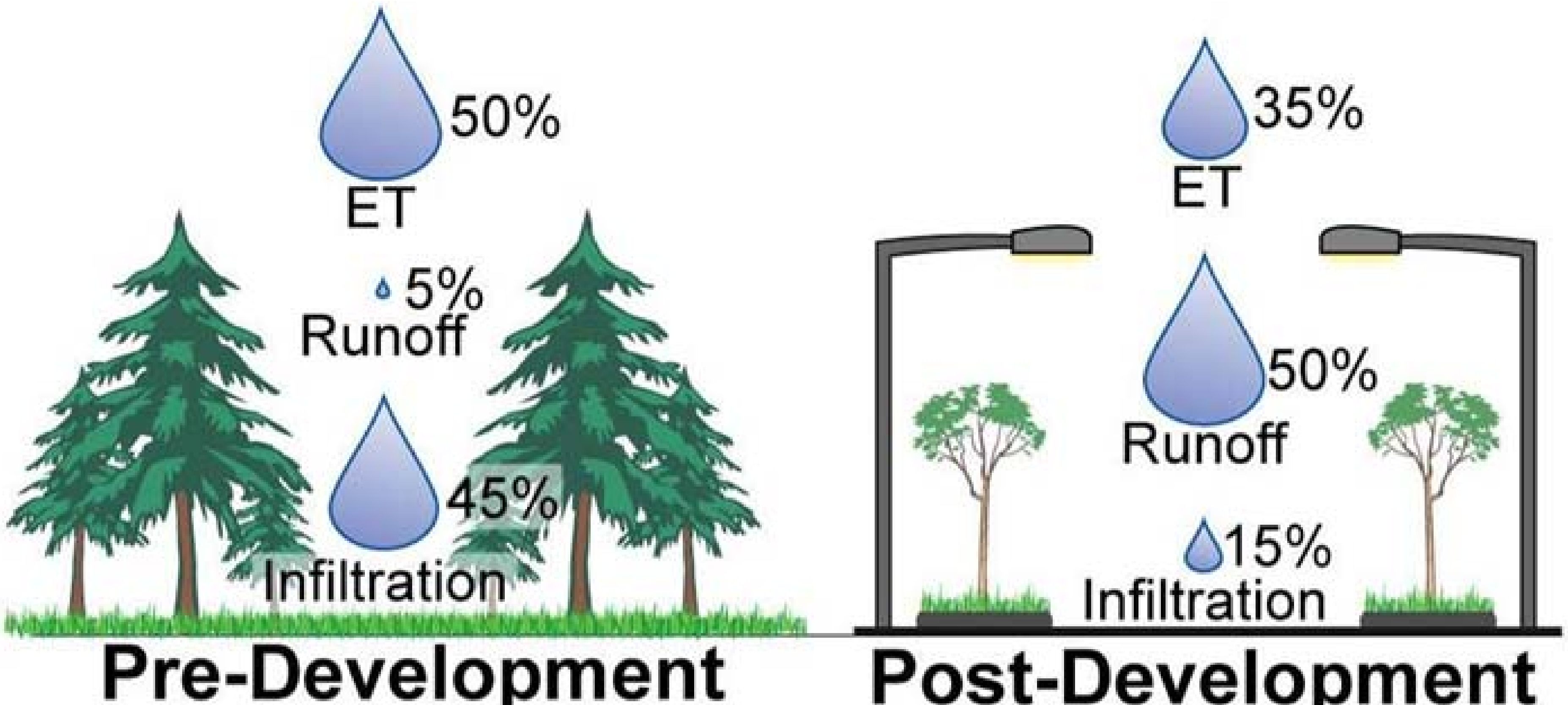


APPLIED RESEARCH ASSOCIATES, INC.

Long-Term Performance and Cost Efficiency

- Introduction to Permeable Pavement
- Design
- Construction
- Maintenance
- Resources
- Questions

Impact of Urbanization



Swank, W.T., and Crossley, D.A. 1988. *Forest Hydrology and Ecology at Coweeta*. New York, NY: Springer-Verlag.

The Problem - Increased Flood Flows

Urban Area Flooding

Permeable Pavements – A Green Solution

- In percolating soils, increases infiltration
- Reduces stormwater volume/peak flows
- Reduces stormwater pollutant load
- Decreases downstream erosion

Early Permeable Pavements

expanding the realm of POSSIBILITY®

Pervious, Porous & Permeable Pavements

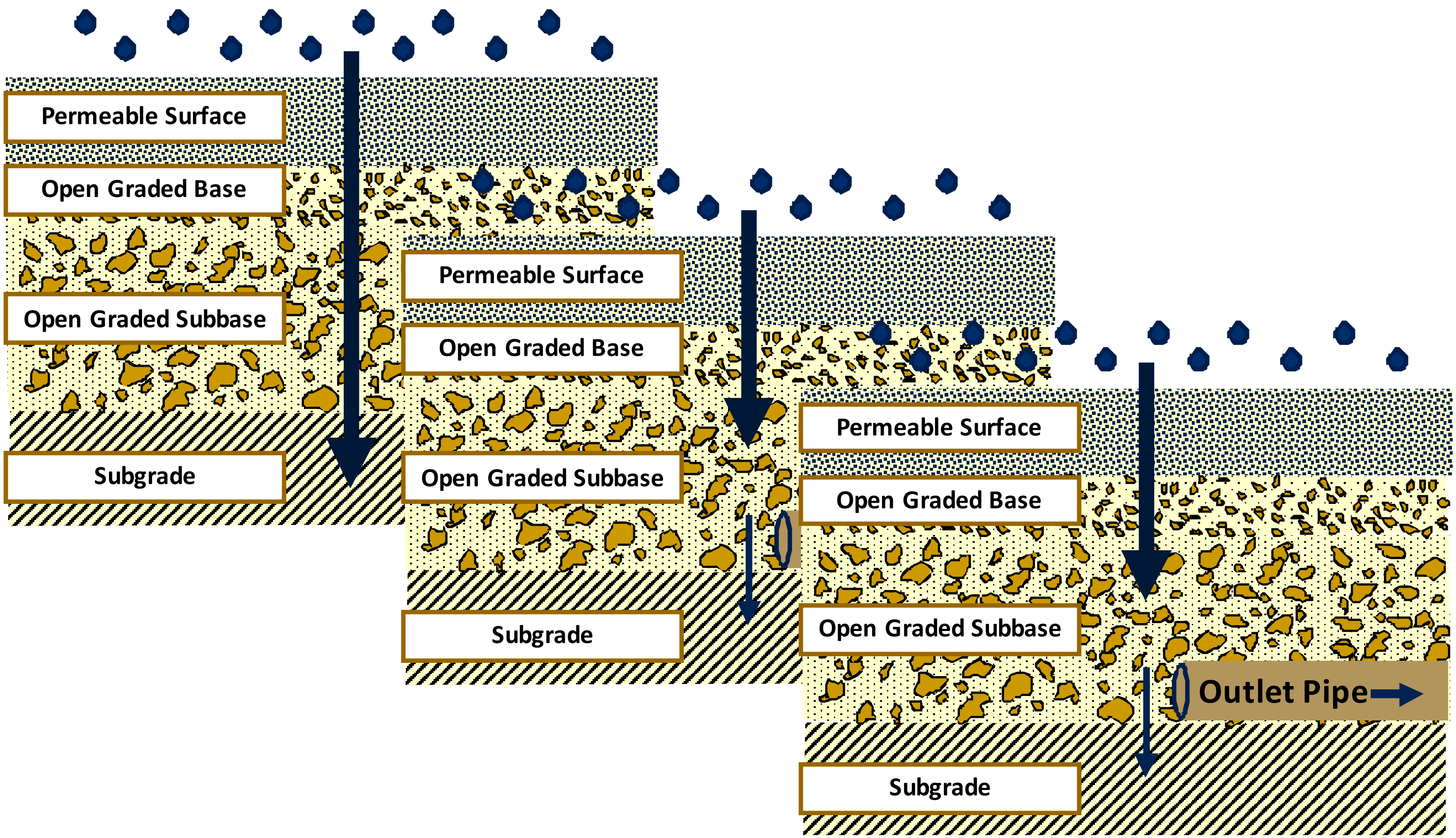
Pavement system designed to permit the infiltration of surface water

Porous Asphalt

Pervious Concrete

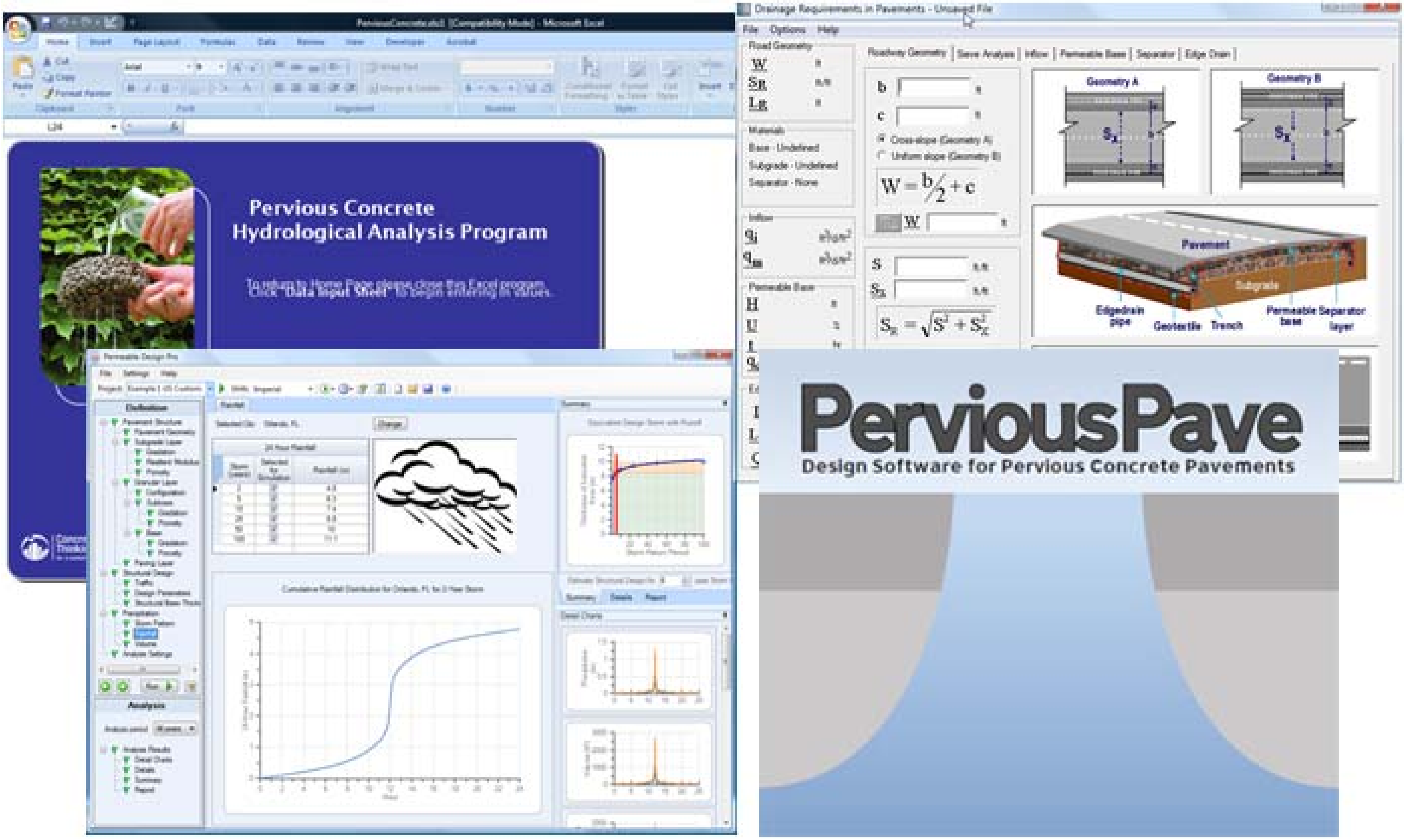
Permeable Interlocking Concrete Pavers

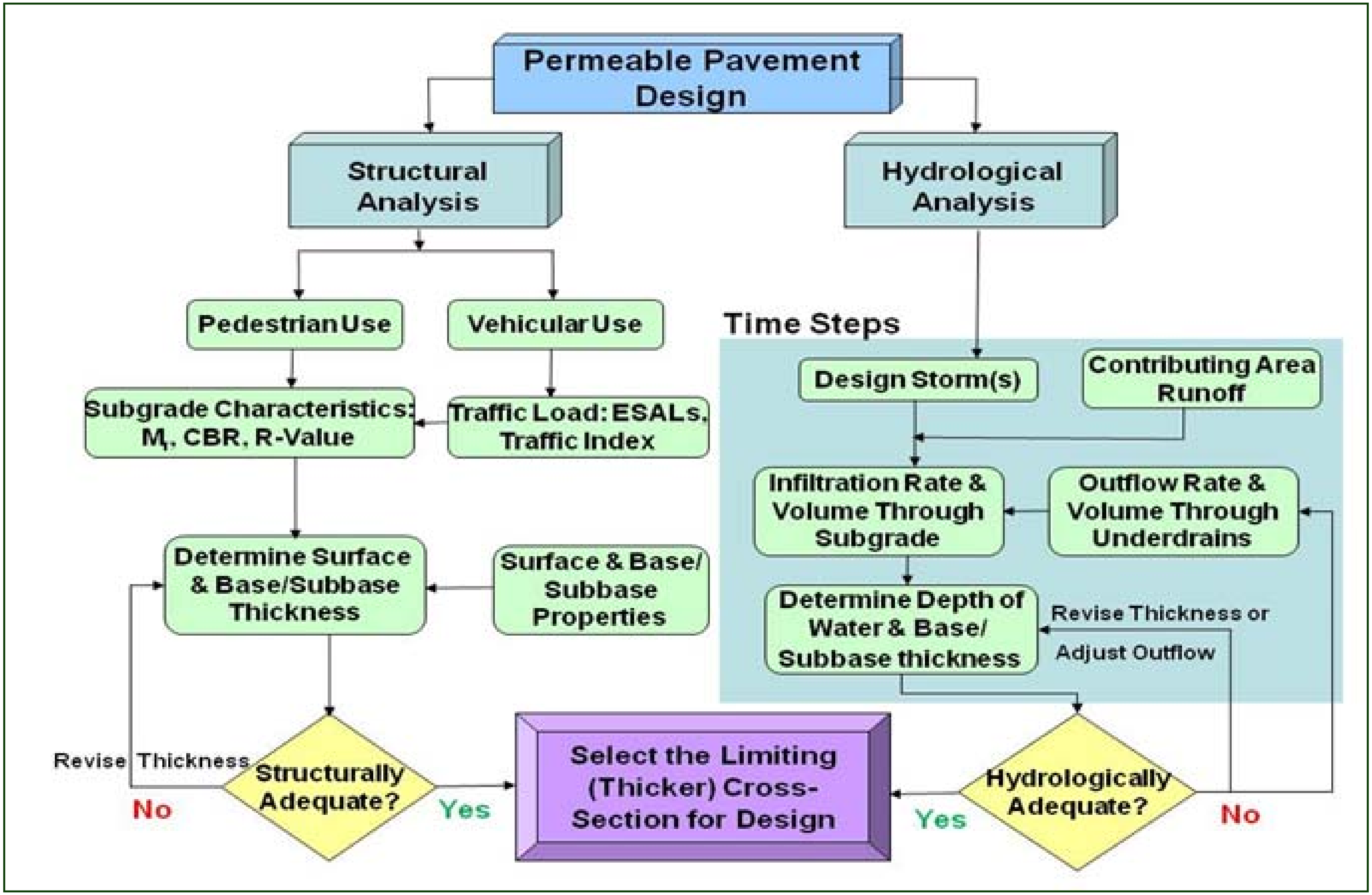
Permeable Pavement Functions



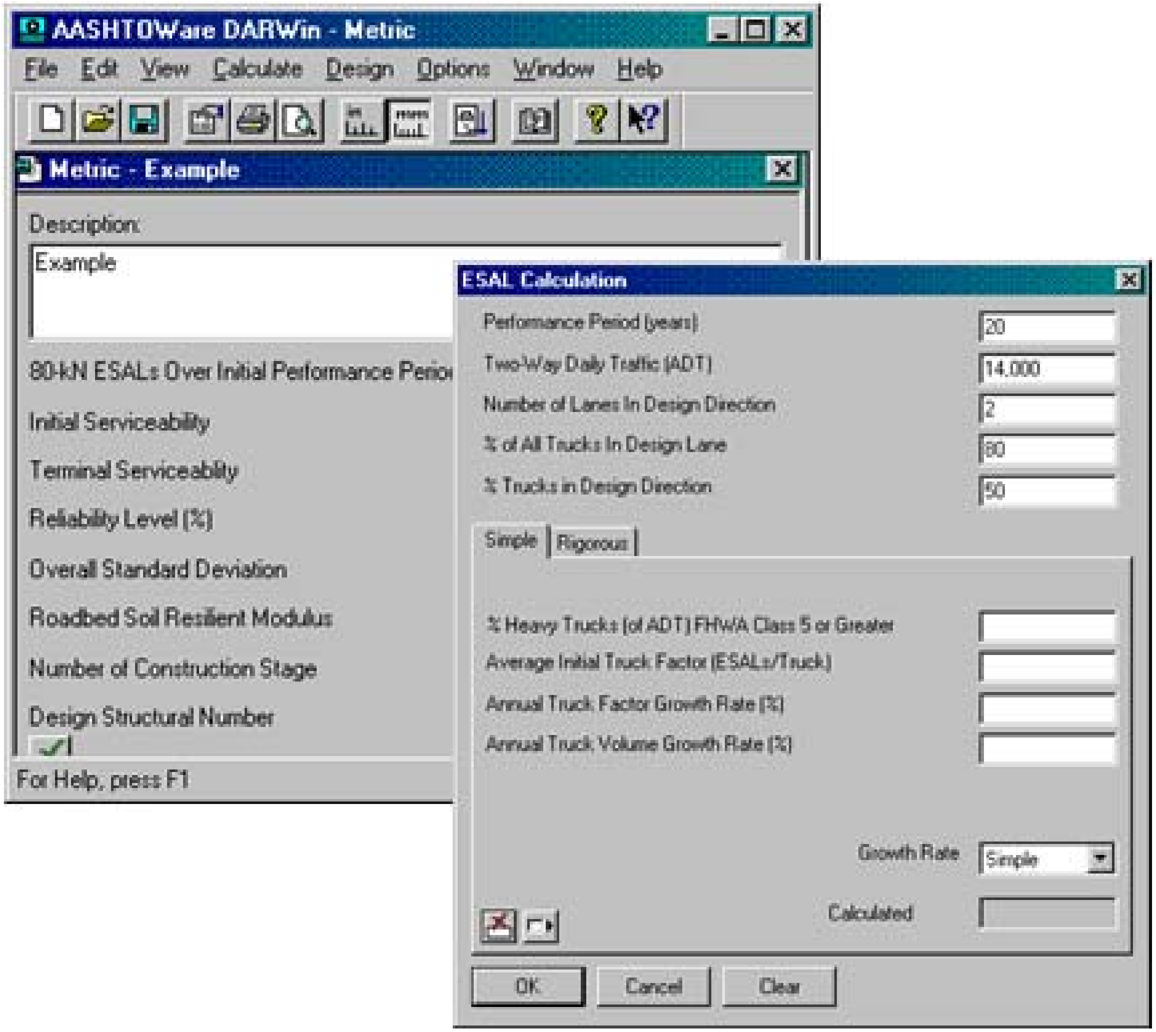
Design Guides

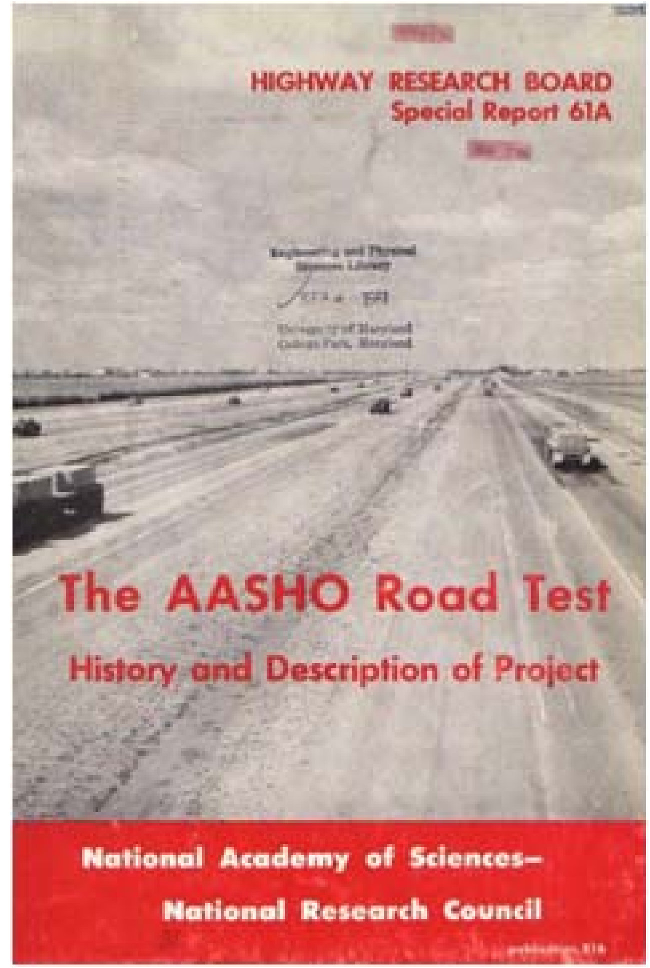
Array of Different Design Tools




Permeable Pavement Design
Structural Analysis
Hydrological Analysis
Pedestrian Use
Vehicular Use
Time Steps
Design Storm(s)
Contributing Area Runoff
Subgrade Characteristics: Mr, CBR, R-Value
Traffic Load: ESALs, Traffic Index
Infiltration Rate & Volume Through Subgrade
Outflow Rate & Volume Through Underdrains
Determine Surface & Base/Subbase Thickness
Surface & Base/ Subbase Properties
Determine Depth of Water & Base/ Subbase thickness
Revise Thickness or Adjust Outflow
Revise Thickness
Structurally Adequate?
No
Yes
Select the Limiting (Thicker) Cross-Section for Design
Yes
Hydrologically Adequate?
No

Structural Design - AASHTO

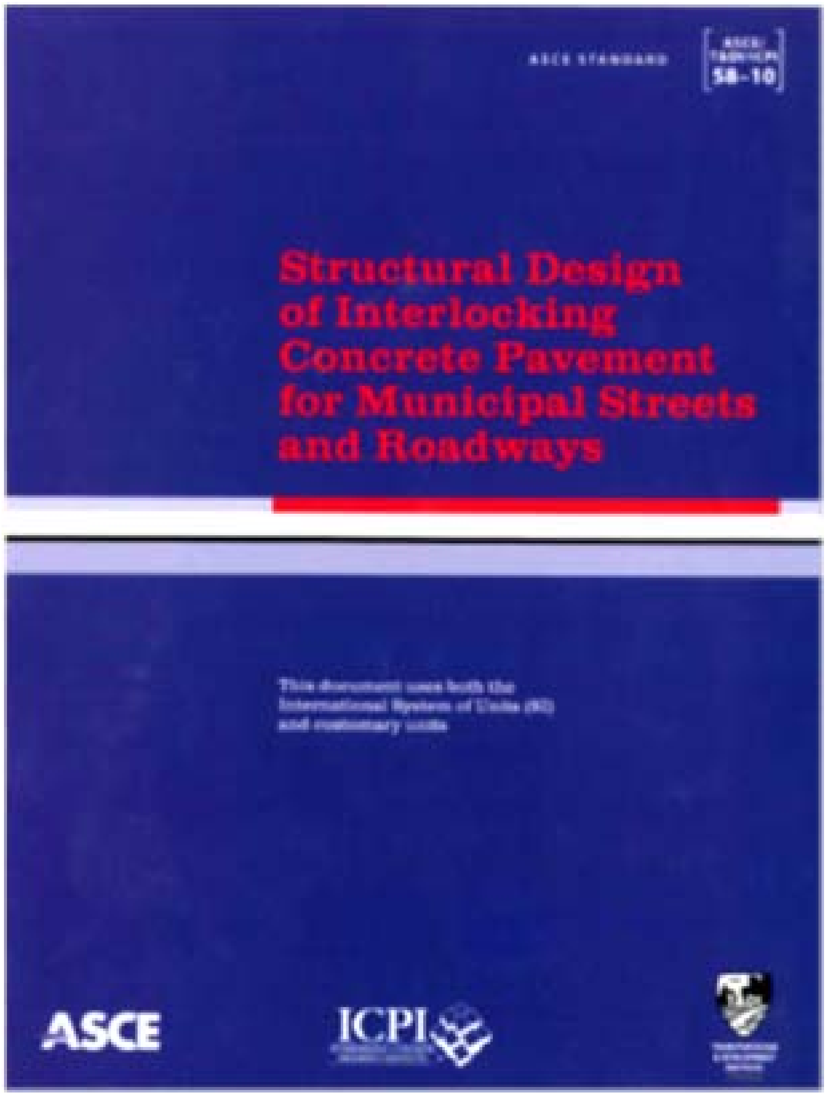




Subgrade Type and Quality

- Subgrade support is one of the most important parameters governing pavement structural design
- Best (complete resilient modulus testing from in-situ materials to determine input values)
- Fair (estimate resilient modulus based on other site or subgrade materials testing, i.e. FWD back-calculation, dynamic cone penetrometer, California Bearing Ratio)
- Poor (select based on 'typical' subgrade type and drainage ability

Subgrade Type and Quality



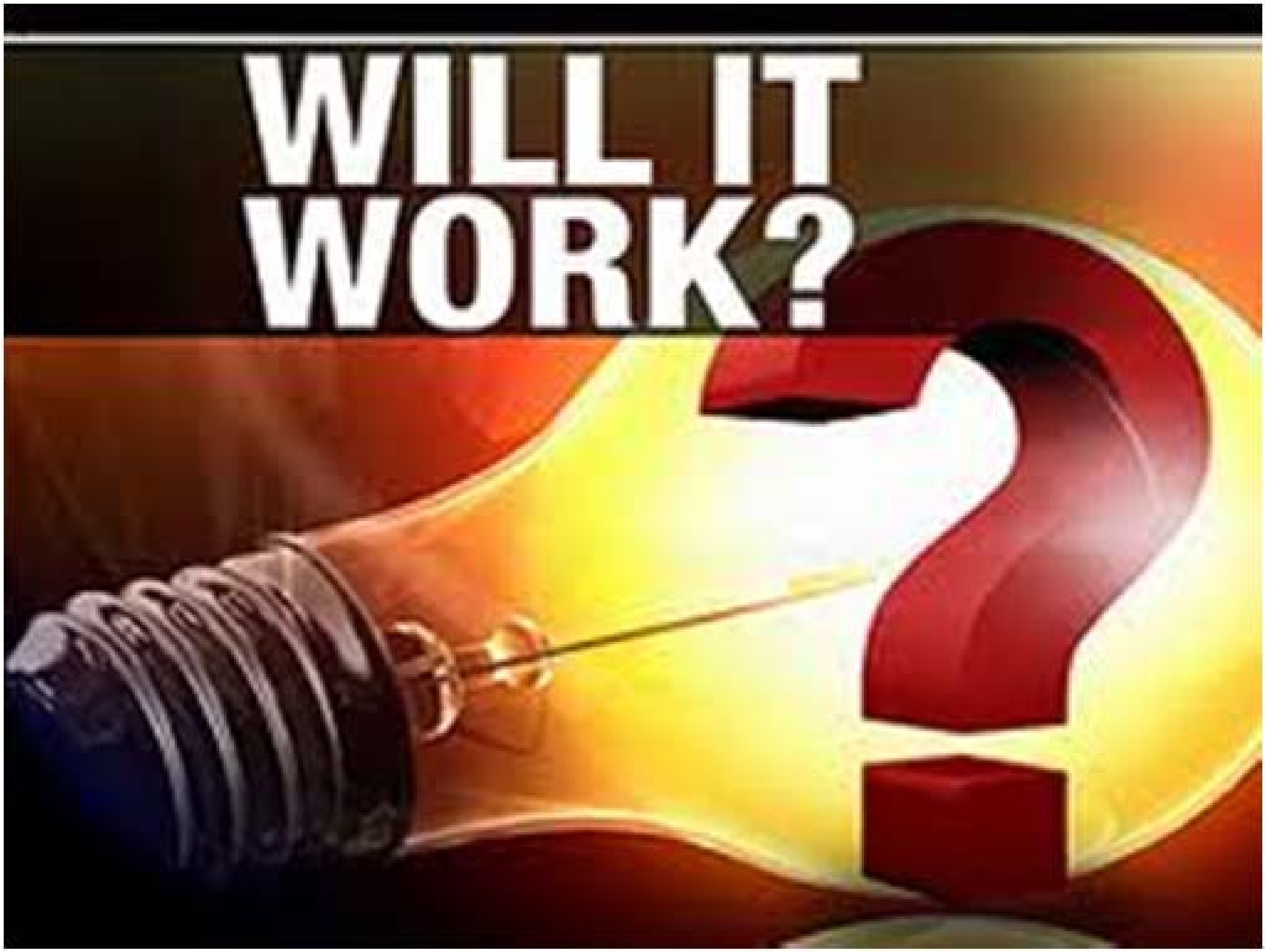
- Possible Source – ASCE 58-10 Publication
- Current ASCE design standard for permeable pavement design under development

Infiltration Test Apparatus

Site Design

Source of Water – Contributing Area

Evaluate Site Suitability



Key Decision Factors

Considerations	Description
Availability of capital funding	The initial capital construction cost of permeable pavement is typically higher than for conventional pavement. Overall long-term life-cycle costs can be very competitive if consideration is given to stormwater quality and quantity benefits are taken into account.
Status of environmental approval	In some jurisdictions, permeable pavement may not be permitted or may require additional environmental approvals.
Proximity to environmentally sensitive areas	The presence of protected watersheds, cold water streams, marshland, etc. may preclude the use of permeable pavement systems or require more extensive treatments.
Safety	Ability to accommodate safety features such as rumble strips, vegetative growth, areas subjected to rapid icing, etc.
Significant longitudinal grades	Not recommended for grades of more than 5 percent as sheet flow may overload the ability of the permeable shoulder to infiltrate water which may cause localized flooding.
Depth of water table	Permeable pavements should not be used in areas where the water table is within 0.6 m (2ft) of the top of the soil subgrade. It must be possible to drain water entering the subgrade.
Significant use of sand and/or salt for winter maintenance	Melting salt will result in higher concentrations of chlorides in the water which may hinder plant growth. Winter sand may clog permeable pavement systems resulting in reduced system permeability.
Risk of accidental chemical spill	Is the permeable pavement location in an area where hazardous chemical transportation is present.

Key Decision Factors

Considerations	Description
Amount and intensity of precipitation	May not be suitable in areas of frequent, high intensity storms.
Presence of utilities	The design and construction of permeable shoulders may be problematic in areas where utilities are present along the roadway shoulders.
Risk of flooding	Areas subject to frequent flooding may require supplemental drainage features to ensure that the roadway surface is properly drained.
Mandates for water quality	Permeable pavements may contribute substantially to water quality improvement.
Mandates for stormwater management	Permeable pavements provide stormwater management alternatives to more costly or complicated practices.
Maintenance protocols	Permeable pavement systems require mandatory non-traditional maintenance practices such as vacuum sweeping.
Shoulder utilization	Some shoulders are used as driving lanes for specification conditions or circumstances, e.g. evacuation routes, rush hour traffic, pullovers for passing, high occupancy vehicle routes, emergency vehicles, etc.
Interest in innovation	Utilizing traditional impermeable surfaces for stormwater management provides opportunities for innovation.
Complexity of geometric conditions	Geometric constraints such as horizontal or vertical grades, presence of bridge structures, curbs, retaining walls, guiderails, etc.
Impact of unknown site conditions	Variability of soil conditions, presence of organics, potential for frost heave, etc. may impact shoulder pavement performance.
Owner experience and resources	The use of permeable pavements for roadway shoulder is very limited a present.

Decision Support Tools

A. Primary Considerations

Part A Weighting: 60

Consideration	Rating	Weighting	Weighted Value	Weighting Guidelines: Low	Medium	High
Availbility of Capital Funding	Medium	20.0	12.0	No specific funding available	Need to justify funding	Project funded
Status of Environmental Approval	Medium	20.0	12.0	Application required	Approval pending	Approved
Proximity to Enviornmentally Sensitive Areas	Low	20.0	4.0	Adjacent	Within watershed area	Outside of watershed area
Safety	High	10.0	10.0	Significant safety issues	Safety issues can be addressed	Minimal safety issues
Significant Grades	High	10.0	10.0	Grades >5 percent	Grades of 3 to 4 percent	Grades <3 percent
Depth of Water Table	Medium	20.0	12.0	Water table < 0.6m below subgrade	Water table 0.6-0.9m below subgrade	Water table > 0.9m below subgrade
Total		**100.0**	**60.0**			
		Weighted Total:	**36.0**			

B. Secondary Considerations

Part B Weighting: 30

Consideration	Rating	Weighting	Weighted Value	Weighting Guidelines: Low	Medium	High
Salt/Sand use for Winter Maintenance	High	10.0	10.0	Used for >4 months	Used 1 to 4 months/year	Used < 1 month/year
Risk of Accidental Chemical Spill	High	10.0	10.0	Located in chemical/industrial area	On major trucking route	Limited exposure
Amount and Intensity of Precipitation	Medium	15.0	9.0	Intense storms	Moderate frequency/intensity	Frequent/non-intense storm
Presence of Utilities	High	10.0	10.0	Critical utilities	Non-critical utilties	None
Risk of Flooding	Medium	10.0	6.0	Frequent	Occasional	None
Mandates for Water Quality	High	10.0	10.0	No concerns	Some water quality issues	Water quality concerns
Mandates for Stormwater Management	High	15.0	15.0	No concerns	Some stormwater management issues	Stormwater management concerns
Maintenance Protocols	Low	10.0	2.0	Minimal maintenance	Reactive maintenance	Proactive maintenance
Traffic Utilization	High	10.0	10.0	Heavy traffic use	Occassional traffic use	Use for emergency use only
Total		**100.0**	**82.0**			
		Weighted Total:	**24.6**			

C. Other Considerations

Part C Weighting: 10

Consideration	Rating	Weighting	Weighted Value	Weighting Guidelines: Low	Medium	High
Interest in Innovation	Low	25.0	5.0	Minimal interest	Innovation encouraged	Regular innovation implementation
Complexity of Geometric Conditions	High	25.0	25.0	Significant geometric restrictions	Some geometric challenges	Minimal geometric restrictions
Impact of Unknown Site Conditions	Medium	25.0	15.0	No site specific information available	Some site information available	Site conditions well known
Owner Experience and Resources	Low	25.0	5.0	No owner experience	Limited owner experience	Significant owner experience
Total		**100.0**	**50.0**			
		Weighted Total:	**5.0**			

Sub Totals

A. Primary Considerations	60	36.0
B. Secondary Considerations	30	24.6
C. Other Considerations	10	5.0
Grand Total	**100**	**65.6**
Decision		**Can Consider**

Decision Range

From	To	Implement Alternative
0	65	No
65	75	Can Consider
75	100	Yes

Decision Support Tools

A. Primary Considerations

Part A Weighting: 60

Consideration	Rating	Weighting	Weighted Value
Availbility of Capital Funding	Medium	20.0	12.0
Status of Environmental Approval	Medium	20.0	12.0
Proximity to Enviornmentally Sensitive Areas	Low	20.0	4.0
Safety	High	10.0	10.0
Significant Grades	High	10.0	10.0
Depth of Water Table	Medium	20.0	12.0
Total		**100.0**	**60.0**
		Weighted Total:	**36.0**

Weighting Guidelines

Low	**Medium**	**High**
No specific funding available	Need to justify funding	Project funded
Application required	Approval pending	Approved
Adjacent	Within watershed area	Outside of watershed area
Significant safety issues	Safety issues can be addressed	Minimal safety issues
Grades > 5 percent	Grades of 3 to 4 percent	Grades < 3 percent
Water table < 0.6 m below subgrade	Water table 0.6-0.9 m below subgrade	Water table > 0.9 m below subgrade

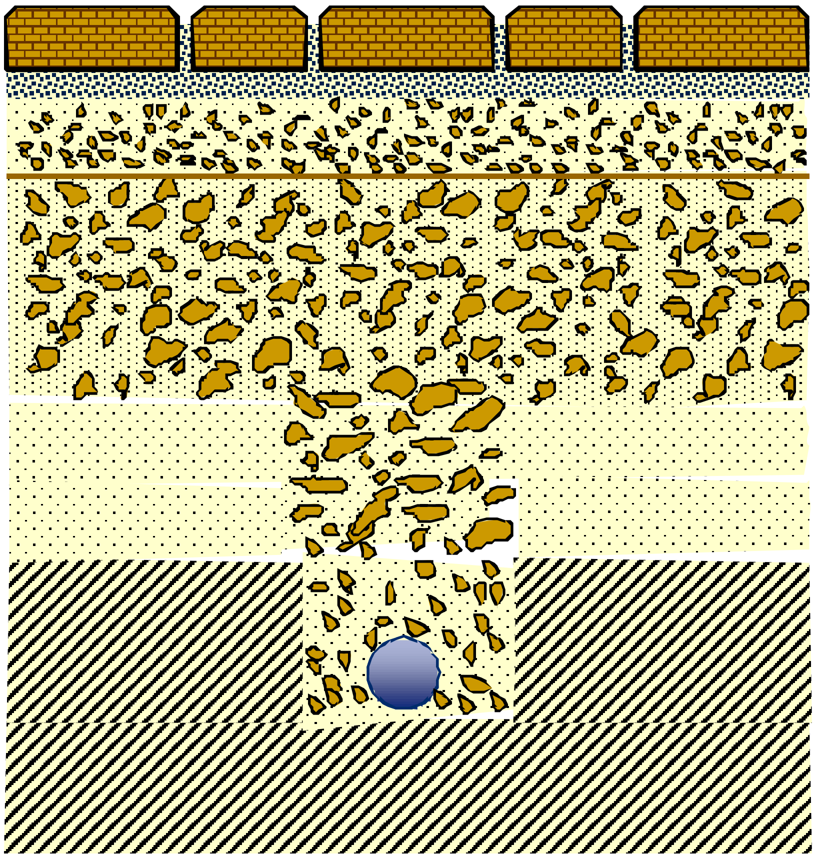
Decision Support Tools

A. Primary Considerations	60	36.0
B. Secondary Considerations	30	24.6
C. Other Considerations	10	5.0
Grand Total	100	65.6
Decision		Can Consider

Decision Range		
From	To	Implement Alternative
0	65	No
65	75	Can Consider
75	100	Yes

Subgrade Preparation

Subdrains



Pavers + (50 mm ASTM #8)
Base (100 mm ASTM #57)
Subbase (200 mm ASTM #2)
Subbase (125 mm CDOT Class 5)

Subdrains

Base Materials

- **Availability**
  - Local DOT aggregate specifications
  - Industry recommendations
  - Local aggregate sources
- **Compaction**
  - No standard Proctor density
  - Establish target density
  - Roller versus plate compactor (parking lot/driveway)
  - Lift thickness
- **Angularity and hardness**

Base/Subbase Compaction

Use the Right Equipment

Not the Wrong Equipment

Final Uniform Surface

Paver Installation

- **Mechanical installation reduces construction time**
- **No curing – immediate availability to traffic**
- **Can be reinstated after repairs**
- **Guide construction specs at www.icpi.org**

Pervious Concrete Installation

Pervious Concrete Installation

Maintenance

- ***Annually*: inspection of observation well after major storm, vacuum and sweep surface – improves infiltration**
- **Maintenance checklist**
- **Model maintenance agreement**


JENNER

Small Scale Permeability Improvements

Larger Scale Maintenance


b

Winter Maintenance

Winter Maintenance

Keep Site Clean During Construction


Permeable


2210
Permeable


Restrict Heavy Vehicles

Permeable Pavement Details/Examples


Zorinsky
Recreation
Complex
Omaha, NE

Thule Street, Colorado


LONDON DRUGS
1 Hour Photo · Computers · Audio·Video · Cosmetics
STOP


Manhattan, Kansas


Sidewalk Features

Main Street - Fort Morgan, Colorado

Toronto Botanical Gardens

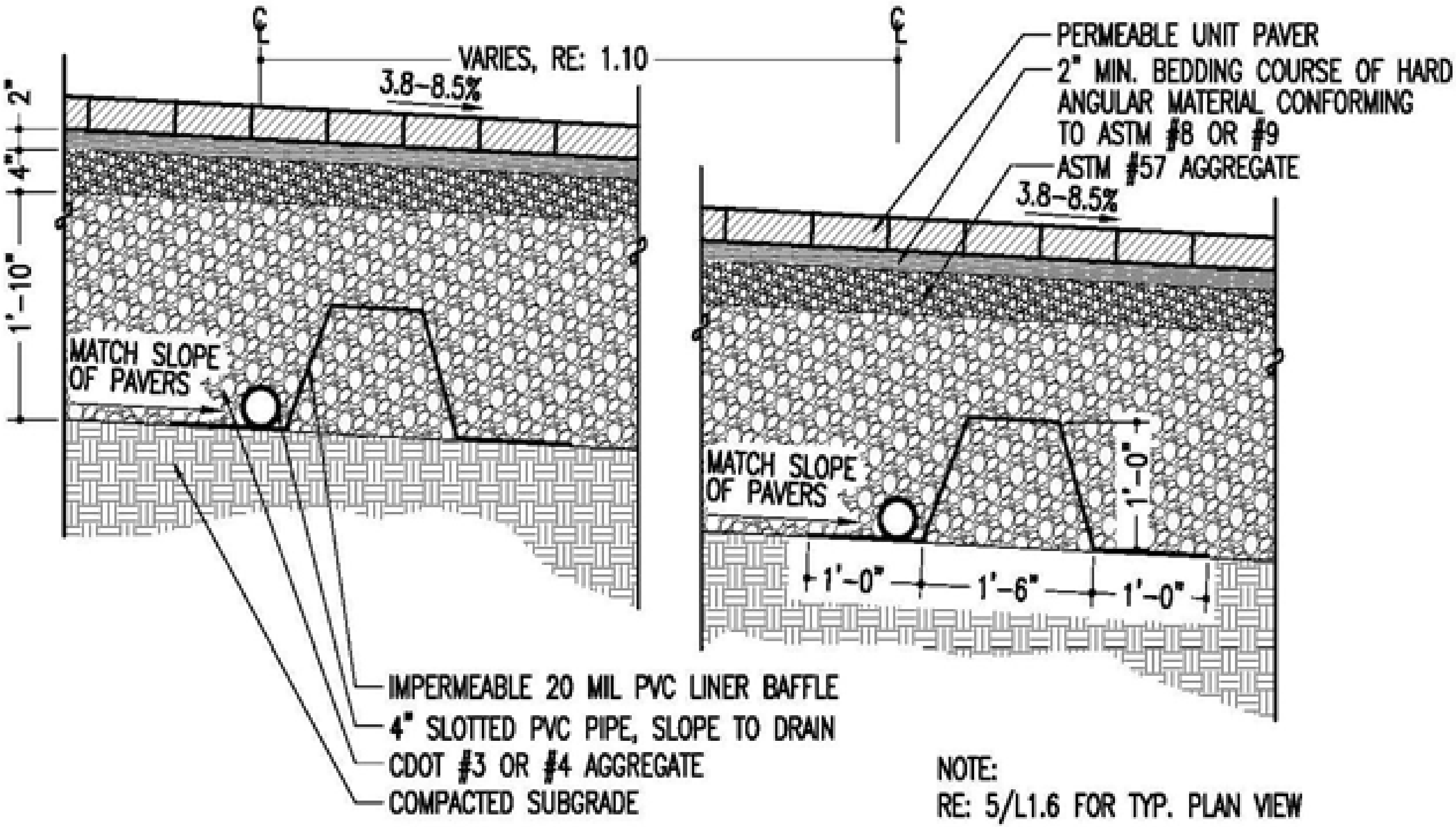
Brampton Veterinary Hospital

Brampton Commuter Parking Lot

Natural Stone


Alleyways

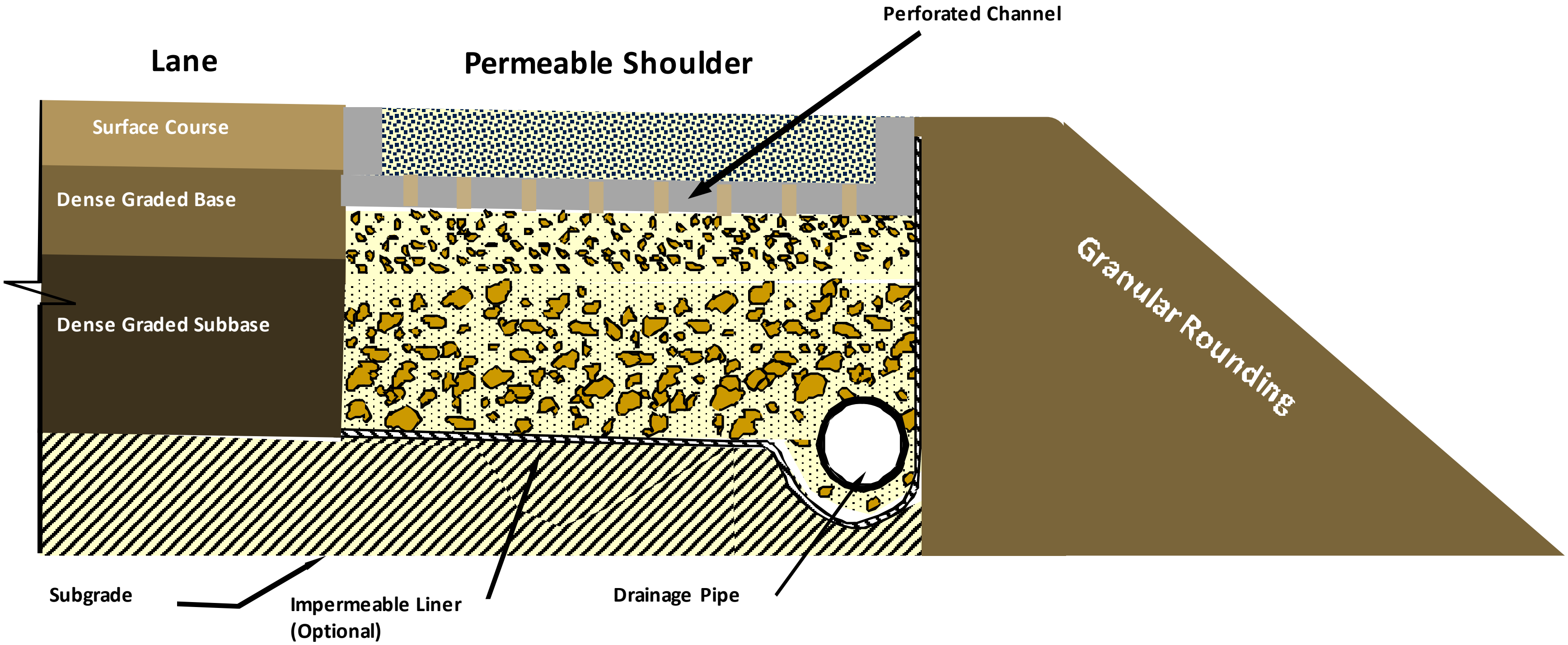
Dealing with Slopes




Alleyway
2010/07/21

Completed Alleyway

Permeable Roadway Shoulders



Detailing – Poor Practice


STORM

Settlement of Base/Subbase

Settlement and Ponding at Transition

Jointing for Pervious Concrete

- Many are not jointed at all – random cracking is not considered a negative on the textured surface

Strange Choice of Joint Location

Poor Construction Joint

Poor Jointing

Special Features of Some Pavers


Loss of Permeability or Heavy Flows


Deep Clogging

Joint Raveling

Large Scale Raveling


High Severity Raveling


High Severity Raveling

Asphalt Raveling


Conventional Paver Surface


Turn into a Permeable Pavement???


What is Wrong Here?


Joint Much Too Wide

Too Complicated


Very Good


No Sliver Pieces
04/03/2009 13:31


Keys to a Successful Project
• Carefully consider the site conditions
• Both structural and hydrological design
• Proper specifications
• Pre-construction meeting
• Inspection during construction
• Keep the site clean
• Make the details count